The New Hampshire Climate Change Policy Task Force

New Hampshire Climate Action Plan

A Plan for New Hampshire's Energy, Environmental and Economic Development Future

Appendix 8:

The Wood Biomass Wedge in New Hampshire: Data Sources and Basic Approach

Prepared by:
John Aber [1] and Matt Frades[2]
March 2009

CARBON SOLUTIONS NEW ENGLAND™
CarbonSolutionsNE.org

[1] Department of Natural Resources and Environment
[2] Institute for the Study of Earth, Oceans, and Space, UNH

The Wood Biomass Wedge in New Hampshire: Data Sources and Basic Approach

John Aber, Department of Natural Resources and Environment
Matt Frades, Carbon Solutions New England
University of New Hampshire
March 2009

I. Introduction and Scope

In December of 2007, Governor John Lynch charged Tom Burack, Commissioner of Environmental Services, with the formation of a Climate Change Task Force to establish goals for reducing greenhouse gas (GHG) emissions, and recommending steps New Hampshire can take to meet those goals. The Task Force has, in turn, engaged Carbon Solutions New England (CSNE) at the University of New Hampshire to act as its technical support organization. CSNE is tasked with providing technical information and quantitative estimates of the effectiveness of a number of different strategies for reducing GHG emissions. The abundant forest resources of the state offer one potential for substituting a renewable energy source for fossil fuel combustion, and lowering the state's GHG footprint.

New Hampshire is roughly 83% forest land (FIA). This has not always been the case. At the peak of the agricultural period in the mid-1800s, more than 50% of the nearly 5.8M (million) acres in the state had been deforested and converted to pastures, croplands and orchards. Through reforestation following the abandonment of agriculture, and recovery from very heavy cutting in the White Mountains around the turn of the 20th century, both the extent of forest cover, and the stocking, total volume, or total biomass of wood in forests has increased steadily. Now, more than 4.8M acres of forest land supports more than 163M tons of woody biomass.

Wood and water were the primary sources of energy in the late 1870s and 1880s when New Hampshire was the most heavily industrialized state in the nation. As both the environmental and economic impacts of the state's dependence on imported energy become more apparent, there is also increasing interest in the potential to once again rely on wood as a primary source of energy.

The purpose of this report is to describe the energy content in the standing crop and annual production of woody biomass in the state, and analyze the potential for the wood resource to contribute to the mix of solutions that will increase the state's energy independence, moderate its energy costs, and reduce its carbon footprint.

II. Methods and Sources of Data

The USDA Forest Service is responsible for periodic inventories of the nation's forest resource. Through its Forest Inventory and Analysis (FIA) program, the Forest Service samples hundreds of thousands of plots nation-wide, one for every 6,000 acres of forest land, on a recurring schedule. Inventories available for New Hampshire were collected in 1983, 1997 and 2002-2005 (nominally 2003). These surveys include measurements of tree volume, sawtimber volume, and a number of ancillary variables from which are calculated tree volume increment, removals (harvest) and mortality. This data base has become the fundamental source for information on the standing crop, growth, and loss, of forest biomass and carbon.

For this study, data were acquired from FIA through their interactive website at: http://www.fia.fs.fed.us/tools-data/default.asp. FIA data for total tree volume, tree volume increment and volume of removals were acquired by county and major forest type. Data were in the form shown in Table 1.

Table 1. Typical format of FIA data available from http://www.fia.fs.fed.us/tools-data/default.asp.

Increment 1997 — **Inventory – New Hampshire, 1997: growth (periodic)**

New Hampshire (33) –Growth :: growing-stock on timberland **(in cuft/year)**

	Grouping of species into 4 major classes				
County	Pine (1)	Other Softwoods (2)	Soft hardwoods (3)	Hard hardwoods (4)	Total
Belknap (1)	1,861,625	975,259	2,535,282	2,487,843	7,860,010
Carroll (3)	4,594,220	4,123,571	5,404,649	6,829,968	20,952,408
Cheshire (5)	5,298,374	2,003,333	1,923,427	5,734,035	14,959,169
Coos (7)	554,746	9,834,463	2,315,805	10,262,354	22,967,367
Grafton (9)	7,709,834	6,791,985	5,624,245	12,217,686	32,343,750
Hillsborough (11)	7,823,960	1,799,760	4,487,269	7,738,598	21,849,587
Merrimack (13)	8,050,720	1,698,152	4,542,885	5,127,683	19,419,441
Rockingham (15)	3,809,470	1,224,621	2,004,704	2,932,855	9,971,650
Strafford (17)	2,417,459	512,875	3,206,043	1,610,797	7,747,174
Sullivan (19)	3,932,669	3,047,971	2,066,797	2,813,271	11,860,708
Totals:	46,053,076	32,011,991	34,111,106	57,755,090	169,931,263

FIA gives the following description of the color-coding of estimated accuracy of the numbers in each data table. "The color of each estimated value represents its percent sampling error (pse); if estimate is **black**, pse is less than or equal to 25%; if estimate is **green**, pse is greater than 25% and less than or equal to 50%; if estimate is **red**, pse is greater than 50%." The greater number of samples at the state level, as opposed to the county level, generally yields the highest accuracy for state-level numbers. Numbers for all of New Hampshire will be the focus here, but data at the county level may be of interest in terms of location of power plants and costs of transportation.

Estimated volumes were converted to estimated biomass using standard values for the density of wood bu species group (in lbs/ft^3 – see http://www.ledinek.com/en/bonus/trees/trees.html), and energy content of wood (6400 BTU/lb, assuming 20% moisture content – see http://bioenergy.ornl.gov/papers/misc/energy_conv.html).
The carbon content of wood is assumed to be 50% of biomass. The CO2 equivalent of wood is the carbon content times 3.67.

Calculations and projections obtained from these data were compared with ecological data from research sites in the state.

III. Results

A. Forest Land Area and Ownership

New Hampshire is approximately 83% forest land (Table 2) held by a relatively large number of small private owners (Table 3).

Table 2. Land area by type in New Hampshire (FIA).

Inventory -- New Hampshire, 2002-2005: all land

New Hampshire (33) --Area of all land (in acres)

County	Land cover					Total
	Accessible forest (1)	Nonforest (2)	Noncensus water (3)	Census water (4)	Denied access (5)	
Belknap (1)	181,835	74,993	--	--	--	256,828
Carroll (3)	531,875	65,756	--	--	--	597,631
Cheshire (5)	390,593	62,141	--	--	--	452,733
Coos (7)	1,096,700	46,179	9,368	--	--	1,152,247
Grafton (9)	966,113	107,704	2,778	--	19,937	1,096,532
Hillsborough (11)	398,639	151,000	835	10,386	10,386	571,247
Merrimack (13)	504,113	93,107	825	2,502	--	600,547
Rockingham (15)	322,660	122,130	--	14,132	--	458,921
Strafford (17)	130,584	95,162	--	--	10,261	236,007
Sullivan (19)	295,588	47,413	919	--	--	343,920
Totals:	**4,818,700**	**865,584**	**14,725**	**27,020**	**40,584**	**5,766,614**

Table 3. Forest land ownership in New Hampshire (FIA).

Inventory -- New Hampshire, 2002-2005: area/volume

New Hampshire (33) --Area of all land (in acres)

County	Ownership						Total
	National Forest (11)	Fish and Wildlife Service (23)	Dept. of Defense or Energy (24)	State (31)	Local (county, municipal, etc.) (32)	private (46)	
Belknap (1)	--	--	--	17,712	--	164,123	181,835
Carroll (3)	161,059	--	--	9,639	19,278	310,679	500,656
Cheshire (5)	--	--	--	41,158	20,579	328,856	390,593
Coos (7)	174,813	21,142	--	95,140	21,142	731,608	1,043,845
Grafton (9)	290,313	--	--	2,538	20,306	620,081	933,238
Hillsborough (11)	--	--	10,583	21,166	9,732	364,700	406,181
Merrimack (13)	--	--	22,256	22,668	20,018	420,957	485,900
Rockingham (15)	--	--	--	10,673	26,664	277,319	314,656
Strafford (17)	--	--	--	--	5,364	131,156	136,519
Sullivan (19)	--	--	--	28,660	13,027	253,901	295,588
Totals:	**626,185**	**21,142**	**32,839**	**249,353**	**156,111**	**3,603,380**	**4,689,010**

B. Initial State-wide Totals and Cross-checks with Ecological Data

Applying the conversion factors described above to the volume tables from FIA yields estimates on total biomass and energy content in standing wood, increment, or removals of the type shown in Table 4.

Table 4. Example of estimates for increments in biomass and energy content of woody biomass from FIA data. These values from the 1997 inventory. Estimated carbon content would 50% of the biomass value. The CO_2 equivalent of the carbon in wood is the carbon value times 3.67.

	Energy (BBTUs/yr)					Biomass (tons/yr)				
	Species Class					Species Class				
County	1	2	3	4	Total	1	2	3	4	Total
Belknap (1)	297	175	607	744	1,823	23,204	13,676	47,402	58,144	142,426
Carroll (3)	733	740	1,293	2,043	4,810	57,265	57,823	101,050	159,624	375,763
Cheshire (5)	845	360	460	1,715	3,381	66,042	28,092	35,962	134,011	264,107
Coos (7)	89	1,765	554	3,070	5,478	6,915	137,905	43,298	239,843	427,961
Grafton (9)	1,230	1,219	1,346	3,655	7,450	96,100	95,242	105,156	285,541	582,038
Hillsborough (11)	1,248	323	1,074	2,315	4,960	97,522	25,237	83,898	180,860	387,517
Merrimack (13)	1,284	305	1,087	1,534	4,210	100,349	23,813	84,938	119,840	328,939
Rockingham (15)	608	220	480	877	2,185	47,483	17,172	37,482	68,544	170,682
Strafford (17)	386	92	767	482	1,727	30,133	7,192	59,943	37,646	134,914
Sullivan (19)	627	547	495	842	2,511	49,019	42,741	38,643	65,749	196,152
Totals:	7,349	5,748	8,166	17,281	38,544	574,034	448,895	637,774	1,349,804	3,010,508

While there is no other comparable data source against which FIA data can be compared, estimates for wood production can be checked against direct measurements made at a few intensive forest research sites across the state, include the Hubbard Brook and Bartlett Experimental Forests located in the White Mountains. Ecological methods for estimating forest production generally include recurring measurements of stem diameters of marked trees, or use of tree cores. Thus these methods include all tree growth before removals or mortality, and results are reported in units of biomass per year and per unit area (e.g. tons per hectare per year). FIA presents data on volume increase and volume removed. Mortality data are not available for New Hampshire, but a rough estimate of mortality over large areas of forest would be 1-2% of standing biomass. The calculations below use 1.5% estimated mortality per year.

Table 5 compares estimates of total wood production from FIA data (increment plus removals plus estimated mortality) with ecological data from 38 forested sites, converted to English tons per acre per year. Overall this comparison is quite good, given the different methods used and the different sampling intensities.

Table 5. Comparison of estimated forest biomass increment for New Hampshire derived from FIA data and ecological estimates (Ollinger and Smith, 2004, Ecosystems 8:760-778)

Ecological Data		FIA Data (Million Tons/year)	1997	2003
Woody Biomass Production		Increment	3.01	2.08
		Removals	2.34	2.25
Mean of 38 sites	g/m2/yr	Mortality	2.43	2.45
	375	Total	7.78	6.78
		Divided by total forest land 4.82M acres		
Mean	(T/acre/yr)	Average (T/acre/yr)		
	1.75		1.61	1.41

C. Woody Biomass: Mass, Production and Energy Potential

The FIA-based estimates of total wood biomass produced by the forest resource can be converted to energy units and compared with the state's energy budget. Table 6 includes estimates derived from the state's Energy Plan of 1999 http://www.nh.gov/oep/programs/energy/StateEnergyPlan.htm and the state profile from the Energy Information Administration http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=NH. The estimate for energy from biomass in Table 6 is derived from the total given in the 1999 NH plan (34,000 BBTUs) reduced by a fraction representing the total reduction in industrial energy production from 1999 to 2007, as estimate by the Energy Information Administration (EIA).

Table 6. Estimated annual energy consumption in New Hampshire by Energy Source [Billion British Thermal Units – BBTUs]

Total Demand by Fuel	
Electric	64,182
Gas	55,337
Oil	176,940
Biomass	19,136
Other	19,834
Total	335,429

Total Energy Content in Standing Biomass: The total energy content in standing biomass in the state in 2003 was 2.1M Billion British Thermal Units (BBTUs), or roughly 6 times the total annual energy consumption in the state. Note that biomass, mostly woody biomass, currently provides roughly 19,000 BBTUs per year, or about 6% of total demand.

Annual Energy in Woody Biomass Increment and Removal: If energy extraction from the forest resources of New Hampshire is to be done in a sustainable manner, then total harvest removals should not exceed annual wood increment. In the FIA data base, the best estimate of total woody increment is "growth" or increment in volume, plus removals (see section 3). Table 7 shows the energy content in "growth", removals, and the total of the two, for the 1997 and 2003 reporting periods. These figures are the starting point for calculations of actual retrievable energy in woody biomass.

Table 7. Estimates of energy content in Increment, Removals and the sum of these two by county for two reporting periods (based on FIA data).

1997 Reporting Period (BBTUs/yr)

County	Increment	Removals	Total
Belknap (1)	1,823	1,680	3,503
Carroll (3)	4,810	3,899	8,708
Cheshire (5)	3,381	1,582	4,963
Coos (7)	5,478	8,029	13,507
Grafton (9)	7,450	4,880	12,330
Hillsborough (11)	4,960	3,245	8,205
Merrimack (13)	4,210	2,719	6,929
Rockingham (15)	2,185	1,639	3,824
Strafford (17)	1,727	846	2,573
Sullivan (19)	2,511	1,444	3,955
Totals:	38,544	29,972	68,516

2003 Reporting Period (BBTUs/yr)

County	Increment	Removals	Total
Belknap (1)	860	1,087	1,947
Carroll (3)	528	1,656	2,184
Cheshire (5)	3,777	1,247	5,024
Coos (7)	2,980	8,866	11,845
Grafton (9)	4,022	3,163	7,185
Hillsborough (11)	4,143	5,520	9,663
Merrimack (13)	3,697	2,613	6,310
Rockingham (15)	3,670	1,411	5,081
Strafford (17)	822	1,399	2,221
Sullivan (19)	2,096	1,873	3,969
Totals:	26,605	28,845	55,449

For these two periods, estimated energy content in woody biomass production is roughly equivalent to the current total demand for electricity in the state (See Table 6).

Several other factors affect the actual availability of this wood resource for energy production. For example, the potential to INCREASE energy capture from this resource is reduced by competition from current uses, including use as an energy source, as well as limitations on harvesting resulting from patterns of ownership and easement restrictions, and the efficiency of the conversion of the resource to a usable form of energy (e.g. electricity or heat).

Ownership, Easements and Set Asides: It is difficult to estimate the impact of ownership patterns and current use or conservation easements on the actual availability of wood from the forests of New Hampshire. The FIA surveys from both 1997 and 2003 suggest that nearly half of the wood production in the state is already being utilized (removals and increment are nearly identical). If we assume that most of this removal occurs from lands without restrictions placed on them, then we need an estimate of the fraction of the unharvested landscape that is available for management. Even more difficult to estimate is the fraction of private land owners that would be willing to enter into the type of long-term management agreement required to ensure a predictable flow of wood to centralized power generating stations. We have estimated that 50% of the currently unharvested forest production might be available for increased energy production, and think that may be overly-optimistic.

Conversion: There is an efficiency factor involved in convert the potential energy in wood to either electricity or heat. In calculating the BTU value of wood, we have assumed only a 20% moisture content. Wood-fired electric power plants use green wood with much higher moisture contents. A number of technologies are available to increase the efficiency of wood combustion, including gasification and co-generation of electricity and heat. We have used an industry-standard value of 12,688 BTU/kWh in the conversion of wood energy content to electricity.

Avoiding An Excess of Wood-Fired Capacity: The data presented here, along with the integrated forest model discussed below, can be used to estimate the total potential for the state's forest resource to support additional wood-fired power plants. Keeping in mind the that there is an upper limit to the amount of woody biomass that New Hampshire's forests can provide for electricity generation and that wood resources from other states and Canada may or may not be available to plants in New Hampshire, it would be prudent to understand the demands that the construction of similar plants in adjacent jurisdictions might place on both their own and New Hampshire's resources.

Upside I – Capturing Forest Mortality: One of the strategies suggested by the Task Force is to increase the capture of biomass in trees that die in the forest prior to harvest. Data in Table 5 suggest that the total energy yield could be increased by as much as 50% if this process were completely efficient in catching each tree as it falls. While the potential to reduce losses to mortality is real, the intensity of management required to achieve this goal is much greater than current practices. This option should be examined more fully, especially in combination with recent proposals to use the revenues from selling cull wood and thinnings from forest management practices for energy to support the cost of increasing the value of the remaining stand. The goal of this practice would be to maximize the use of wood in the final harvest for high quality products such as solids and veneers. This could also help to realize another proposed Task Force strategy of increasing the diversion of wood products from short-term pools, such as paper, to long-term pools, such as furniture and building materials.

Upside II: Decentralized Use of Wood for Home Heating: The efficiency of converting wood energy to electricity is reduced by the use of green wood. Large plants with tremendous throughputs of wood do not have the time or space to dry the biomass before burning. This can be compared with the relatively high efficiency of small-scale commercial or home units in which the wood can be allowed to dry before burning, and can be used either in a cogeneration system or in a more efficient traditional wood stove. Efficiencies of 60%-90% are achievable.

Integrated Forest Model:

A model of net carbon emission/sequestration was constructed incorporating data obtained primarily from the Forestry Inventory and Analysis (FIA) National Program, from a Society for the Protection of New Hampshire Forests (SPNHF) study, and from personal communication with experts in the forestry and wood products industry. The basic approach of using FIA data to estimate the potential energy content of New Hampshire wood is described in the supporting document "The Wood Biomass Wedge in New Hampshire." A more detailed and comprehensive description of the forest and wood products model is in preparation for print in a peer-reviewed journal.

This model estimates exchanges of carbon between terrestrial woody biomass sinks and the atmosphere. Changes in standing woody biomass are modeled by county (10 counties) and by FIA forest classes (4 classes) as a result of primary productivity, mortality, forest conversion, and harvest. Decomposition and storage in the dead wood pool is included in the model. The fate of harvested wood is partitioned into slash and cull, low grade products (pulp, cordwood, or bark), and mill products (rough lumber, chips, sawdust, or bark.) Mill product use is modeled as durable product, non-durable product, or wood for energy (electricity or home heating.)

The model projects the future size of the terrestrial woody biomass carbon sink, the annual net sequestration of forests, and the annual avoided fossil fuel emissions. Net avoided emissions from various forest and wood management scenarios are compared against a business-as-usual (BAU) scenario. The basic structure of the model is represented in a schematic in Figure 1. This model has been used to calculate the net effect of land use changes, harvest changes, and wood use for products and for energy on carbon in an integrated fashion.

Figure 1: Simplified conceptual model of the carbon implications of the forestry and wood product business-as-usual scenario.